CLAIMS

What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. A back end of the line (BEOL) interconnect structure comprising:

(a) an ultralow k (ULK) dielectric, having a dielectric constant of up to about 3, and conductive metal features provided on a substrate;

(b) a liner barrier layer between said ULK dielectric and said conductive metal features; and

(c) a thin dielectric layer (TDL), having a thickness of up to about 5 nanometers, between the liner barrier layer and the ULK dielectric, wherein the TDL comprises a dense dielectric film having hermetic barrier capability, said film comprising a different material than the material of the ULK dielectric.

2. The interconnect structure of claim 1, wherein the TDL has a thickness ranging from about 0.5 nanometers to about 5 nanometers.

3. The interconnect structure of claim 2, wherein the TDL exhibits conformal deposition and is essentially defect free.

4. The interconnect structure of claim 1, wherein the TDL has a thickness ranging from about 1 nanometer to about 3 nanometers and a conformality that is at least about 0.5.

5. The interconnect structure of claim 4, wherein the TDL material is selected from the group consisting of silicon nitride (SiN), SiC, SiCH, SiNH, SiCNH, SiCOH, AlN, BN, SiCBN, CN, and alloys, mixtures, and multilayers of the same.

6. The interconnect structure of claim 5, wherein the TDL material is selected from the group consisting of:

(i) materials of formula:

$$Si_xO_wN_yH_z,$$

wherein x ranges from about 0.35 to about 0.45, w ranges from 0 to about 0.1, y ranges from about 0.45 to about 0.55, and z ranges from 0 to about 0.2;

(ii) materials of formula:

$$Si_xO_vC_wN_yH_z,$$

wherein x ranges from about 0.2 to about 0.3, v ranges from 0 to about 0.1, w ranges from about 0.25 to about 0.35, y ranges from about 0.1 to about 0.2, and z ranges from 0 to about 0.35; and

(iii) materials of formula:

$$Si_xC_wO_yH_z,$$

wherein x ranges from about 0.22 to about 0.32, w ranges from about 0.15 to about 0.3, y ranges from about 0.3 to about 0.5, and z ranges from 0 to about 0.3.

7. The interconnect structure of claim 6, wherein the TDL material comprises a composition of formula $Si_xC_wN_yH_z$, wherein x = about 0.25, w = about 0.3, y = about 0.15, and z = about 0.3.

8. The interconnect structure of claim 1, wherein the TDL is deposited by a method selected from the group consisting of: high density plasma (HDP), downstream HDP, electron cyclotron resonance (ECR), plasma enhanced chemical vapor deposition (PE CVD), assisted PE CVD, and plasma enhanced atomic layer deposition (PE ALD).

9. The interconnect structure of claim 5, wherein the liner barrier layer is selected from the group consisting of Ta, TaN, Ti, TiN, W, WN, and alloys, mixtures, and multilayers of the same; the ULK dielectric is selected from the group consisting of SiCOH and porous SiCOH materials with a dielectric constant ranging from about 1.5 to about 3.0; and the conductive metal features are selected from the group consisting of Cu, Al, Ag, Au, W, and alloys, mixtures, and multilayers of the same.

10. The interconnect structure of claim 9, wherein the liner barrier layer is selected from the group consisting of Ta, TaN, and alloys, mixtures, and multilayers of the same; and the conductive metal features comprise Cu.

11. The interconnect structure of claim 2, wherein the ULK dielectric has a dielectric constant ranging from about 1.5 to about 3.0; and the TDL has a dielectric constant ranging from about 2.8 to about 7.

12. A method for making a back end of the line (BEOL) interconnect structure comprising:

a) providing an ultralow k (ULK) dielectric, having a dielectric constant of up to about 3, on a substrate;
b) forming single or dual damascene etched openings in said ULK dielectric;
c) providing a thin dielectric layer (TDL), having a thickness of up to about 5 nanometers, on the etched openings of said ULK dielectric, wherein the TDL

comprises a dense film having hermetic barrier capability, said film comprising a different material than the material of the ULK dielectric;

d) providing a liner barrier layer on the TDL;

e) providing a conductive metal to fill said etched openings; and

f) subjecting the structure to a planarization process.

13. The method of claim 12, wherein the TDL has a thickness ranging from about 0.5 nanometers to about 5 nanometers.

14. The method of claim 13, wherein the TDL exhibits conformal deposition and is essentially defect free.

15. The method of claim 12, wherein the TDL has a thickness ranging from about 1 nanometer to about 3 nanometers and a conformality that is at least about 0.5.

16. The method of claim 15, wherein the TDL material is selected from the group consisting of silicon nitride (SiN), SiC, SiCH, SiNH, SiCNH, SiCOH, AlN, BN, SiCBN, CN, and alloys, mixtures, and multilayers of the same.

17. The method of claim 16, wherein the TDL material is selected from the group consisting of:

(i) materials of formula:

$$Si_xO_wN_yH_z,$$

wherein x ranges from about 0.35 to about 0.45, w ranges from 0 to about 0.1, y ranges from about 0.45 to about 0.55, and z ranges from 0 to about 0.2;

(ii) materials of formula:

$$Si_xO_vC_wN_yH_z,$$

wherein x ranges from about 0.2 to about 0.3, v ranges from 0 to about 0.1, w ranges from about 0.25 to about 0.35, y ranges from about 0.1 to about 0.2, and z ranges from 0 to about 0.35; and

(iii) materials of formula:

$$Si_xC_wO_yH_z,$$

wherein x ranges from about 0.22 to about 0.32, w ranges from about 0.15 to about 0.3, y ranges from about 0.3 to about 0.5, and z ranges from 0 to about 0.3.

18. The method of claim 17, wherein the TDL material comprises a composition of formula $Si_xC_wN_yH_z$, wherein x = about 0.25, w = about 0.3, y = about 0.15, and z = about 0.3.

19. The method of claim 12, wherein the TDL is deposited by a method selected from the group consisting of: high density plasma (HDP), downstream HDP, electron cyclotron resonance (ECR), plasma enhanced chemical vapor deposition (PE CVD), assisted PE CVD, and plasma enhanced atomic layer deposition (PE ALD).

20. The method of claim 16, wherein the liner barrier layer is selected from the group consisting of Ta, TaN, Ti, TiN, W, WN, and alloys, mixtures, and multilayers of the same; the ULK dielectric is selected from the group consisting of SiCOH and porous SiCOH materials with a dielectric constant ranging from about 1.5 to about 3.0; and the

conductive metal is selected from the group consisting of Cu, Al, Ag, Au, W, and alloys, mixtures, and multilayers of the same.

21. The method of claim 20, wherein the liner barrier layer is selected from the group consisting of Ta, TaN, and alloys, mixtures, and multilayers of the same; and the conductive metal comprises Cu.

22. The method of claim 13, wherein the ULK dielectric has a dielectric constant ranging from about 1.5 to about 3.0; and the TDL has a dielectric constant ranging from about 2.8 to about 7.

23. A method for making a back end of the line (BEOL) interconnect structure comprising:

a) providing an ultralow k (ULK) dielectric, having a dielectric constant of up to about 3, on a substrate;

b) forming single or dual damascene etched openings in said ULK dielectric;

c) placing said structure in a process chamber on a cold chuck at a temperature ranging from about -200°C to about 25°C;

d) adding a sealing agent to the process chamber; and

e) performing an activation step.

24. The method of claim 23, wherein the activation step comprises exposing the structure to electron beam radiation or UV radiation while the structure remains cold, at a temperature ranging from about -200°C to about 25°C.

25. The method of claim 24, wherein the electron beam radiation uses an electron energy ranging from about 0.5 to about 100 keV, with a dose of about 10 to about 1,000 microCuries/cm^2, at a time of about 1 second to about 170 minutes.

26. The method of claim 23, wherein the activation step comprises heating the structure to a temperature ranging from about 300°C to about 450°C for about 1 second to about 170 minutes in vacuum or a non-oxidizing reactive ambient.

27. The method of claim 26, wherein the non-oxidizing reactive ambient is selected from the group consisting of hydrogen/argon and ammonia.

28. The method of claim 23, wherein the activation step comprises exposure of the structure to a plasma while the structure remains cold, at a temperature ranging from about -200°C to about 25°C.

29. The method of claim 28, wherein the plasma comprises a component selected from the group consisting of H_2, N_2, NH_3, He, Ar, CH_4, C_2H_6, C_2H_4, C_2H_2, and mixtures of one or more of the same.

30. The method of claim 23, wherein the sealing agent comprises a cyclic siloxane compound.

31. The method of claim 30, wherein the cyclic siloxane compound is selected from the group consisting of tetramethylcyclotetrasiloxane (TMCTS) and octamethylcyclotetrasiloxane (OMCTS); and the ULK dielectric is selected from the group consisting of SiCOH and porous SiCOH materials with a dielectric constant ranging from about 1.5 to about 3.0.

32. The method of claim 23, wherein the sealing agent comprises a mixture of NH_3 and a methylsilane or a higher silane.

33. The method of claim 23, wherein the TDL is deposited in an etch tool or a deposition tool.